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Systems with composite or nonlinear structure are of great importance to current science and technology. Under this grant, we have inverstigated several such system: nonlinear optical media, fluids with vortex motion, ~~rerfied~~ gases and compisite elastic or eletrostatic materials. Our research goals have been to derive mathematical theories or models for these systems, to develop numerical algorithms and compute solutions for the resulting equations, and to mathematically analyze the equations. For example, for sustems with microscopic variation, such as a composite elastic material or a rerfied gas, we derived theories that describe the systems on a macroscopic scale. For nonlinear systems with singularities, such as nonlinear optics or vortex synamics, we find simple descriptions of the development of the singularities and performed numerical solutions with singularities to verify the simpler theories. (KR)

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Effective Behavior of Composite and Nonlinear Media

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The emphasis of our research is on analytic and computational methods for studying behavior of complex materials and fluids. This represents a long-standing research program, but in the last year it has operated in conjunction with the Center for Analysis of Heterogeneous and Nonlinear Media. In addition to the research described under that program, the following represent a few of our research projects:

1. **Macroscopic Properties of Composite Materials.** We have developed a general framework for deriving bounds on the effective properties of composite materials, generalizing the celebrated Hashin-Shtrikman bounds. In this general framework, it is possible to incorporate high order statistical information about the composite material. We have also extended the Hashin-Shtrikman bounds to several new physical problems.

2. **Kinetic Theory.** We have developed an analytic theory for the Milne and Kramer's problems for a rarefied gas, with applications to heat and mass flux in liquid vapor systems. In addition we have solved the problem of shock stability for a simplified model of the Boltzmann equation. Although not surprising physically this was a major outstanding mathematical problem, and the method of solution should be useful in a number of other problems.

3. **Propagation of Phase Transition Interfaces.** We have numerically solved the fluid equations with a van der Waals equation of state for the pressure. This theory, which predicts phase transitions, is controversial, but our results should contribute to an understanding of its validity. We are able to classify some of the phase transitions fronts as stable and some as unstable, and to show the possibility of non-uniqueness of stable solutions of the Riemann problem for this system.

4. **Diffusion of Interaction Particles.** We have developed a theory for describing the long-time asymptotics of particles which are interacting and undergoing Brownian motion. The result is an effective diffusion coefficient, which can be either larger or smaller than that for the Brownian motion alone. This result has applications for the study of suspensions of particles in a fluid.